MASSACHUSETTS

# INSTITUTE OF TECHNOLOGY,

BOSTON, MASS.

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## DEPARTMENT

OF

## NAVAL ARCHITECTURE.



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# COURSES OF INSTRUCTION

AT THE

# MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

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COURSE I. — CIVIL ENGINEERING.
II. — MECHANICAL ENGINEERING.
III. — MINING ENGINEERING AND METALLURGY.
IV. — ARCHITECTURE.
V. — CHEMISTRY.
VI. — ELECTRICAL ENGINEERING.
VII. — BIOLOGY.
VIII. — PHYSICS.
IX. — GENERAL STUDIES.
X. — CHEMICAL ENGINEERING.
XI. — SANITARY ENGINEERING.
XII. — GEOLOGY.
XIII. — NAVAL ARCHITECTURE.

# COURSE XIII.

## NAVAL ARCHITECTURE.

THE course in Naval Architecture recently established at the Massachusetts Institute of Technology provides a thorough training in the theory and methods of designing and building ships, together with a study of the properties requisite for safety and good behavior at sea. Like the other twelve courses it is arranged to occupy four years, and leads to the degree of Bachelor of Science. It is intended to cover the same ground and accomplish the same results as the English and French government schools for training Naval Constructors. Like all the courses at the Institute it is intended to give, in addition to professional and technical training and equipment, a good scientific and liberal education.

This branch of instruction has been developed in a conservative manner, beginning five years ago as an option of the course in Mechanical Engineering; and still retains a large portion of the work of that course, including steam engineering and a study of the marine engine. It is believed that the best coördination of the design of a steamship and its propelling machinery can be attained by a naval constructor who is familiar with both branches of his profession. Attention is directed mainly to the construction of merchant steamships; but some attention is given to problems arising in the design of men-of-war, which offer at once the most definite and the most intricate questions presented to the naval constructor. Some attention also is given to sailing-vessels.

Lectures in naval architecture are given twice a week throughout the third and fourth years; these are accom-

panied by two or three exercises a week in drawing, in which the students make the calculations and constructions described in the lectures, and thus gain a proper appreciation of the principles learned, and some degree of facility in applying them.

The subjects treated in the lectures are as follows:

(*a*) Description of the methods of building ships in iron and steel; including transverse and longitudinal framing, and the fitting of ballast tanks and double bottoms; preparing the ground, laying blocks, and erecting scaffolding; the laying out, bending, and erection of the framing and the application of the shell plating; the fitting of decks, hatches, and bulkheads; launching and docking.

(*b*) Proofs and application of the methods of finding areas and volumes, and of finding moments, moments of inertia and the radius of gyration of lines, areas, and volumes by the trapezoidal rule, Simpson's rule, and by the Amsler-Laeffel integrator.

(*c*) General discussion of the properties of floating bodies, with special application to ships. Discussion of the curves and surfaces of buoyancy and flotation, the metacentre and metacentric curves. Statical and dynamical stability of ships and curves of statical and dynamical stability, with examples of such curves for special types of ships. Application of the metacentric method to various problems; such as the experimental determination of the centre of gravity of a ship when afloat, the variation of stability due to the addition or removal of a weight, and the effect of moving a weight already on board. Calculation of trim and of changes of trim due to moving a weight. Discussion of the effect of carrying fluids in tanks wholly or partially filled; of the effect of filling water-tanks wholly or partially; of the effect of filling compartments of a ship, both when intact and when broken open to the sea. Reserve of stability, or the effect of sud-

den forces,— such as gusts or squalls of wind,— or the safety of a ship when under sail.

(*d*) Methods of finding statical and dynamical stability proposed by Barnes, Benjamin, Spence, McFarlane-Grey, Daymard, and others.

(*e*) Methods of finding the weight and centre of gravity of hull, equipment, and cargo. Determination of the loads, shearing forces, and bending moments acting on the hull of a ship in still water and when borne by waves. Determination of the equivalent girder and the stresses on the hull of a ship.

(*f*) Rolling of ship in an unresisting medium, in water, and among waves.

(*g*) The trochoidal theory of waves, and the theory of waves of translation. Waves made by ships and the effect of such waves on the propulsion of ships.

(*h*) Resistance of ships due to friction, wave-making, eddy-making, and to the effect of the wind on hull and rigging. Experiments on the resistance of ships by towing and otherwise. Experiments on models of ships in a tank; results obtained by W. Froude and R. E. Froude. Effect of the propeller on the resistance of a ship.

(*i*) Propulsion of ships by steam or sails. Sail plans, centre of effort and centre of resistance of a sailing-ship. (Marine propellers, paddle-wheels, and screws are discussed under the head of Marine Engineering.)

(*k*) Steering and manœuvring a ship under steam and under sail.

(*l*) Methods of procedure for laying out the preliminary design of a ship for a given purpose. Methods of carrying out and completing a design.

The drawing-room work is as follows:

(*a*) Laying out and fairing the lines of a ship.

(*b*) Making a displacement sheet in the ordinary form. Determination of displacement by the aid of the Amsler-Laeffel integrator.

(*c*) Drawing curves of displacement, tons per inch of immersion, centre of gravity, centre of buoyancy, areas of water-line, and transverse metacentre.

(*d*) Determination of metacentric stability.

(*e*) Calculation of statical and dynamical stability by Barnes' method and the method in use at the Bureau of Construction and Repair of the Navy Department.

(*f*) Calculation of the weight and centre of gravity of the hull, equipment, and cargo.

(*g*) Calculation of trim of a ship, with and without cargo.

(*h*) Calculation of the stresses on the hull in still water and when borne by waves.

(*i*) Designing and laying out the lines of a ship for a given service.

(*k*) Drawing the midship section of a ship, the general deck plans, etc.; getting out the specifications for the scantlings.

The drawing-room work is carried on progressively, as applied to some ship or ships of good modern design, and is of a scope to give familiarity with all the methods and processes used for the complete design of a ship and the determination of her properties. This work is carried out as completely as it would be for a man-of-war, the requirements and limitations of the merchant service being kept in view. Finally, the design of a ship is begun and carried far enough to exhibit the methods of designing; calculations and processes which the student has already mastered and which must be familiar before a design can be intelligently begun, are carried only so far as is required to get the design into shape.

The Marine Engineering of the fourth year of the course is the complement of ship designing; the following statement of subjects will give an idea of the scope and quality of the work:

(*a*) Descriptions of marine and stationary engines in all their details, including the most modern types.

(*b*) The usual discussion and calculation of the strength and the proportions of the parts of marine engines.

(*c*) Discussion of the probable behavior of the steam in cylinders with different combinations and arrangements.

(*d*) Discussion of the effect of the reciprocating parts in combination with the preceding, with the object of determining the greatest stresses on the parts of the engine.

(*e*) Comparison of these results with the results of the usual methods.

(*f*) Discussion of paddle-wheels and screw-propellers.

The last four, viz., (*c*), (*d*), (*e*), and (*f*), include a large amount of drawing-room work and calculations by the students.

The department has a good collection of standard and recent works on naval architecture and marine engineering, and has the advantage of the large and complete libraries of engineering, physics, chemistry, etc., belonging to the Institute. There is, further, in the possession of the department a large number of drawings of modern ships and marine engines of various types for naval and merchant service; including complete sets of drawings of several steamships, with their propelling machinery, both naval and merchant, of large size and of the most recent and approved design and construction. Much of this material is worked up in such form that it can be used directly in the work of the classes; in fact, the work as detailed could be carried out only by aid of such material.

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Attention has been given, so far, only to the special work of the department; the more general but no less important work of the course requires attention in order that a just idea may be had of the value of the course.

The choice of courses in the Institute is made at the end of the first term of the first year, but the differentiation in this year is slight. Attention is called to the fact that the mathematics, physics, and drawing (including descriptive geometry) of this year and the next are of vital importance, and that success in future work cannot be expected without a thorough understanding of them.

In the second year, the more essential subjects are analytic geometry, differential calculus, physics, and mechanism. Practice is given in making working drawings of machines from measurement, and other drawings, illustrating the class-room work. Instruction is also given in forging and in chipping and filing, at the shops.

The more important third-year subjects are:

(*a*) Integral Calculus.

(*b*) Physics, including a special study of Heat, and work in the physical laboratory.

(*c*) Applied Mechanics, devoted mainly to a mathematical study of the strength of materials.

(*d*) Valve gears and link-motions.

(*e*) Thermodynamics and Steam Engineering. This course includes a detailed study of the principles of Thermo-dynamics, mathematically treated; a discussion of the properties of gases and vapors, especially steam; of the flow of steam and other fluids; of the steam injector; and of the hot-air engine. All of these topics are treated in such a way as to give the student a good foundation in the principles of Thermodynamics, especially as they apply to the steam-engine. This is followed by a study of the steam-engine itself, of the compound and multiple-expansion engine, and of the mode of testing steam-engines; the remainder of the course being devoted to a study of steam-boilers.

(*f*) Drawing. With the exception of a short course in mechanism design, requisite for the proper understanding of valve gear, link motion, and other details, the drawing of this year and of the fourth year is given in connection with the special work in naval architecture as above described.

(*g*) Engineering Laboratory Work. This is given during the second term, and is devoted to drill in steam-engine tests, for which the 9-inch, 16-inch, and 24-inch by 30-inch Allis triple-expansion engine and also the 8-inch by 24-inch Harris-Corliss engine are used.

The following list will give an idea of the fourth-year work not already detailed:

(*a*) Applied Mechanics. The earlier work in this subject aims to familiarize the students with such data on the strength of materials used in construction as have been obtained by means of experiments, especially those made on a practical scale, in different parts of the world. Pains are taken to keep this work well up to date. This is followed by a study of friction and lubrication, of continuous girders, of stone and iron arches, and of the theory of elasticity. Besides the above, each student has made during the present school year (1892–93) the following tests in the laboratory:

1. A test to determine the modulus of elasticity, the limit of elasticity and tensile strength of a cast-iron, or wrought-iron, or steel rod or bar, or the transverse strength of a coupling.
2. A test of the deflections, and of the transverse strength of a full-size iron or steel I-beam, or of a wooden beam subjected to a transverse load.
3. A test to determine the modulus of elasticity, and the tensile strength of annealed or bright iron wire.
4. A test to determine the shearing modulus of elasticity of a shaft.
5. Tests of the tensile strength of hydraulic cement.
6. Tests of the compressive strength of hydraulic cement.

The acquisition during the present year of the 300,000-pounds Emery testing machine, built by Sellers & Co., of

Philadelphia, has greatly enriched the course in applied mechanics.

(*b*) Steam Engineering. A careful study is made of such data as have been based on reliable tests made on large, single, compound, and multiple-expansion engines in different parts of the world. The gas-engine is also studied.

(*c*) Hydraulics. The main principles of hydraulics are taught, including the flow of water through orifices and pipes and over weirs.

(*d*) Industrial Management. This involves a study of the organization and relations of the various departments of an industrial establishment, both in the office and in the workshop, the conduct of accounts, the methods of compensating labor and of superintendence, and the effect upon cost of production of interest, and other forms of expense.

(*e*) Engineering Laboratory Work. This can be best illustrated by a list of the tests made during the past year (1892-93) by each student. It is as follows, viz.:

Test of the transmission of power by belting.

Test of the performance of a surface condenser.

Test of a direct acting steam-pump.

Test of the flow of steam.

Valve setting, (plain side valve and double valves, and for Corliss engines).

Test of a pulsometer.

Test of a centrifugal pump.

Calibration of orifices for the flow of water.

Determination of the clearance of an engine.

Use of the Webber dynamometer.

Use of the Emerson power scale.

Testing gauges by means of the mercury column.

Test of a 208-horse power boiler, the test continuing for 128 hours, each man working eight hours.

Test of the steam injector.

Use of three different kinds of calorimeters.

Test of a Swain turbine.

Test of a rotary pump.

Measurement of the flow of water by means of orifices and weirs.

Test of a water motor.

Test of an Ericsson hot-air engine.

Analysis of chimney gas.

Test of a battery of boilers of 416-horse power, the test lasting 56 hours, each student working eight hours.

Application of Hirn's analysis to the triple-expansion engine in the laboratory.

Each test is performed by a squad of from two to five students, and then the results are worked up and handed in within two or three days by each member of the squad.

(*f*) Heating and Ventilation (a short course).

(*g*) Metallurgy (a short course).

(*h*) Dynamo-electrical Machinery (a short course).

(*k*) Shopwork, including machine tool work, and that portion of chipping and filing not completed in the second year.

(*l*) The thesis.

The thesis required of every candidate for graduation involves the investigation of some assigned problem. It provides for more special and independent work in some line of the profession.

The engineering laboratories of the Institute of Technology — the first of their kind to be established — are too well known to require description here. A separate circular has been issued giving an account of their organization and equipment, copies of which can be had on application to the secretary of the Institute.

# SCHEDULE OF THE COURSE

IN

# NAVAL ARCHITECTURE.

## FIRST YEAR.

| FIRST TERM. | SECOND TERM. |
|---|---|
| Solid Geometry.<br>Algebra.<br>General Chemistry.<br>Chemical Laboratory.<br>Rhetoric and English Composition.<br>French (or German).<br>Mechanical Drawing.<br>Freehand Drawing.<br>Military Drill. | Plane and Spherical Trigonometry.<br>General Chemistry; Qualitative Analysis.<br>Chemical Laboratory.<br>Political History since 1815.<br>French (or German).<br>Mechanical Drawing and Descriptive Geometry.<br>Freehand Drawing.<br>Military Drill. |

## SECOND YEAR.

| FIRST TERM. | SECOND TERM. |
|---|---|
| Principles of Mechanism.<br>Forging.<br>Analytic Geometry.<br>Descriptive Geometry.<br>Physics.<br>English Literature.<br>American History.<br>German (or French). | Mechanism: Gear-Teeth; Machine Tools.<br>Drawing.<br>Forging, Chipping and Filing.<br>Differential Calculus.<br>Physics.<br>English Literature and Composition.<br>German (or French). |

## THIRD YEAR.

| FIRST TERM. | SECOND TERM. |
|---|---|
| Naval Architecture.<br>Naval Architectural Drawing.<br>Steam Engineering; Valve Gears; Thermodynamics.<br>Integral Calculus.<br>General Statics.<br>Physics: Heat.<br>Physical Laboratory.<br>German (or French).<br>Mechanism Design. | Naval Architecture.<br>Naval Architectural Drawing.<br>Steam Engineering; Boilers.<br>Engineering Laboratory.<br>Strength of Materials; Kinematics and Dynamics.<br>Physical Laboratory.<br>English Composition.<br>German (or French). |

## FOURTH YEAR.

| FIRST TERM. | SECOND TERM. |
| --- | --- |
| Naval Architecture. | Naval Architecture. |
| Naval Architectural Drawing. | Naval Architectural Drawing. |
| Steam Engineering. | Engineering Laboratory. |
| Hydraulics. | Strength and Stability of Structures; Theory of Elasticity. |
| Dynamics of Machines. | Political Economy. |
| Engineering Laboratory. | Marine Engineering. |
| Chipping and Filing; Machine-Tool Work. | Thesis. |
| Strength of Materials; Friction. | |
| Metallurgy of Iron. | |
| Heating and Ventilation. | |
| Elements of Dynamo Machinery. | |
| Marine Engineering. | |

# OFFICERS OF INSTRUCTION

## In Naval Architecture.

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Cecil H. Peabody, S.B., Associate Professor of Steam Engineering, in charge of the Department of Naval Architecture.

Gaetano Lanza, C.E., Professor of Theoretical and Applied Mechanics.

Peter Schwamb, S.B., Associate Professor of Mechanism and Director of the Workshops.

Dwight Porter, Ph.B., Associate Professor of Hydraulic Engineering.

Jerome Sondericker, C.E., Assistant Professor of Applied Mechanics.

Allyne L. Merrill, S.B., Assistant Professor of Mechanism.

Edward F. Miller, S.B., Assistant Professor of Steam Engineering.

Bertrand R. T. Collins, S.B., Instructor.

George W. Hamblet, S.B., "

Carleton A. Read, S.B., "

James Swan, S.B., "

## ASSISTANTS.

Fred A. Wilson, S.B.; Phillips P. Bourne; Charles E. Fuller, S.B.; William A. Johnston, S.B.; Walter M. Newkirk, S.B.; Charles F. Park, S.B.; Dwight P. Robinson, A.B., S.B.; Edward C. Wells, S.B.

# OFFICERS OF INSTRUCTION

## In other Related Departments.

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John D. Runkle, Ph.D., LL.D., Walker Professor of Mathematics.

George A. Osborne, S.B., Professor of Mathematics.

Charles R. Cross, S.B , Thayer Professor of Physics, and Director of the Rogers Laboratory.

Silas W. Holman, S.B., Professor of Physics.

Webster Wells, S.B., Professor of Mathematics.

Linus Faunce, S.B., Assistant Professor of Drawing.

S. Homer Woodbridge, A.M., Instructor of Heating and Ventilation.

Theodore B. Merrick, Instructor in Woodwork and Foundrywork.

James R. Lambirth, Instructor in Forging.

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# ADMINISTRATIVE OFFICERS OF THE INSTITUTE.

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